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assistance and suggestions were ever ready for the scientific inquirer.

He died of acute bronchitis on December 14, 1887.

He was elected a Fellow of this Society April 13, 1849.

Alfred Morris was born at Warrington in 1837. A few years after his birth his father removed to London, where the son received his education. On arriving at manhood he visited most of the Australian colonies, as well as Tasmania and New Zealand, and finally settled at Sydney, New South Wales, where he entered the Government service as a civil engineer. He was employed upon the reservoirs for the new water supply, and in laying out some of the new railways, in the course of which work he surveyed a large portion of the New South Wales territory. He was subsequently appointed to the Public Works Department of Western Australia, and while engaged in laying out a new system of roads in this colony he overworked himself in a very hot season, and incurred an illness which terminated fatally on February 28, 1887.

He was a Fellow of the Geological Society of London, and was much thought of as a lecturer on geological and astronomical subjects, as he had the gift of imparting to others the knowledge he himself possessed.

He was elected a Fellow of the Society January 13, 1882.

Balfour Stewart was born on November 1, 1828. He went to school at Dundee, but entered St. Andrew's University at the age of thirteen, and thence passed on to Edinburgh, where he studied under Professor Forbes. Leaving college when he was eighteen years old he was sent by his parents to serve his apprenticeship in business with a firm at Leith, and went out to Australia with a cousin, James Balfour, to start on a commercial career. But he was never fond of business, and soon returned home to Edinburgh, where he became assistant to Professor Forbes in 1853. In 1859 he was appointed Director of Kew Observatory, and held this post until 1870, when he was appointed Professor of Physics at the Owens College, Manchester. He died of apoplexy on December 18, 1887, at Ballymagarvey, near Drogheda, whither he had gone to spend the Christmas holidays.

Balfour Stewart's name was first prominently brought before the public by his researches on radiant heat. His paper was presented to the Royal Society of Edinburgh, and read on March 10, 1858. It contains an account of experiments and arguments on the necessary relationship between the radiation and absorption of a substance. The whole science of spectrum analysis is founded on that relationship, and Stewart deserves a prominent place in the history of this branch of physics.

It is almost impossible now to realise the unsatisfactory and vague ideas which pervaded nearly all writings on the radiation

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of heat during the first half of this century. Stewart was the first to show that radiation was not a pure surface phenomenon, but that it was necessary to take account of the internal radiation of bodies. He proved that if a semi-transparent body is placed in an enclosure of uniform temperature it must make up by its own radiation and reflection whatever heat it has absorbed from the enclosure. Kirchhoff shortly afterwards, and independently, treated the same subject, and it is interesting to compare the two memoirs. Stewart's reasoning is simpler, but it does not allow us to express the law in the definite and mathematical form in which it was published by Kirchhoff.

Stewart proved that the streams of radiant heat crossing any point of an enclosure are not altered by the interposition of a body, whether opaque or transparent. But the radiation crossing any point is made up of heat which has passed through different thicknesses of the transparent bodies and in various directions. What Stewart established for the sum of these streams Kirchhoff proved for each individually. The reasoning thus becomes much more complicated, but the proof more complete. Stewart showed that the law must hold for each description of heat, that is to say, for the radiation of the different wave-lengths separately: it is this generalisation which forms the foundation of the theory of spectrum analysis.

From the time of his appointment to the Directorship of the Kew Observatory until his death, Stewart's attention was principally given to the subject of cosmical physics. The connection between solar phenomena and meteorology fascinated him, and he spent much thought and labour in the investigation of this difficult and important subject. Broadly speaking, the facts are these: Certain phenomena are observed on the Sun to vary periodically. The regular magnetic oscillations, as well as the irregular magnetic disturbances, show in their behaviour a marked correspondence with the state of the solar surface. No physical theory exists to account for the connection. Unless we admit some unknown force, the Sun can only act on the Earth either by gravitation (tidal action), by radiation, or by direct electric discharges. Considering that we have no evidence whatever as to the constancy of the Sun's radiating power to within about 10 per cent., it seems only reasonable to try whether we can detect the same periodicities in meteorological and in solar phenomena.

Balfour Stewart paid attention especially to the shorter periods which have been detected or suspected in solar activity. The problem, in the absence of a well-defined physical theory, is one of very great difficulty, for it is almost impossible to decide in how far accidental regularities may mislead, and how far irregularities may hide effects, which are admittedly small. Balfour Stewart was always cautious in his statements, and tried to verify his results by repeating his reductions whenever he had an opportunity of attaining fresh material. His death is a great loss to the cause he had so much at heart, for much remains to

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be done, and there are few who are willing to undergo the great labour of computation with the risk of obtaining no definite result in the end. It is impossible to give in detail an account of all Stewart's investigations bearing on sun-spots, terrestrial magnetism, and meteorology, and it will be sufficient to mention the more important results which seem well established.

Employing both Carrington's observations and those made at Kew, he, in conjunction with De la Rue and Loewy, investigated the size of sun-spots, as they passed over the solar disc, in relation to the position of the inner planets and *Jupiter*. It was found that the average size of spots attains its maximum on that side of the Sun which is turned away from *Venus* or from *Mercury*, and to have its minimum opposite these planets. This behaviour is so decided with regard to *Venus* that the whole body of observations could be split up into two parts, namely, Carrington's series and the Kew series, in each of which it is distinctly manifest.

The sun-spot period, with its average duration of about eleven years, shows very great irregularities both in the length and in the amplitude of the oscillation. Stewart has shown that from the year 1780 to 1870 the curve of solar activity can be best represented as a superposition of three oscillations, one of ten-and-a-half, one of twelve, and a minor one of about sixteen years. The irregularities would thus be produced by the beats of these three fluctuations. As regards the connection between magnetical and meteorological phenomena, perhaps the most satisfactory results were obtained in his late researches conjointly with Mr. L. Carpenter, in the connection between magnetic disturbances and the strength of the wind. A good case is made out for the conclusion that high and low disturbance values of magnetic force correspond with, and slightly precede, high and low wind values.

Balfour Stewart was the author of several text-books. His "Primer of Physics," as well as his "Elements of Physics," are well established as sound and clear elementary books. His book on heat is an excellent treatise, and his "Lessons in Elementary Practical Physics," written jointly with Mr. W. W. Haldane Gee, is the most complete exposition of experimental methods in Physics which has been written. He contributed to the International Scientific Series an admirable treatise on the Conservation of Energy. Stewart was also the author of the article "Terrestrial Magnetism" in the last edition of the *Encyclopædia Britannica*. The Royal Society Catalogue of Scientific Papers gives a list of 75 papers of which Prof. Balfour Stewart was either the sole or joint author. He was elected a Fellow of the Royal Society in the year 1862, and obtained the Rumford Medal in 1868. At the time of his death he was President of the Physical Society, and of the Manchester Literary and Philosophical Society.

He was elected a Fellow of this Society April 12, 1867.

A. S.